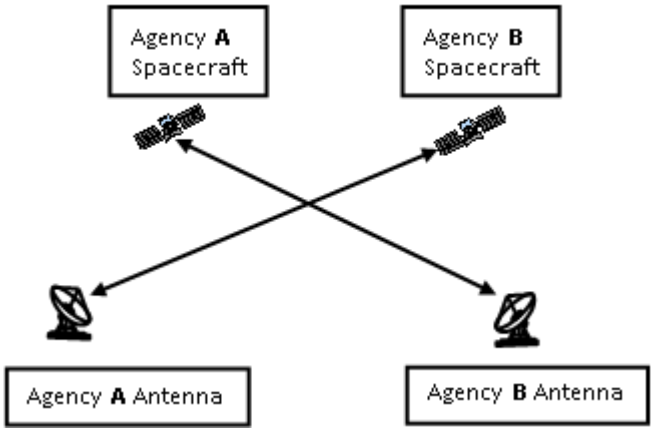
Latest Status of the CCSDS Optical Communications Working Group

March 2022

Bernard Edwards / NASA / Working Group Chair

Optical Communications International Standardization

- **Sharing optical communication ground stations or relay satellites among the international space agencies would allow the agencies to share the cost of the communications infrastructure.**
  - **For example, due to cloud blockage, it is critical to have multiple ground stations in use during space-to-ground optical operations to provide high availability.**
- **International cross support is being worked within the Interagency Operations Advisory Group (IOAG) and the Consultative Committee for Space Data Systems (CCSDS).**
- **The goal is to develop optical communications cross support by various agencies as we have today in traditional Radio Frequency (RF) communications.**



Traditional International RF Cross Support

CCSDS Optical Communications Working Group

- **Scope – (1) Physical, coding, and synchronization layer recommendations for the interoperability of flight and ground optical communications terminals; (2) Recommendations for characterizing the atmosphere channel and for the concept of operations for space-to-ground links**

- **The Working Group has been investigating the following scenarios or "needs" for optical communications:**
  - **High Data Rate**
  - **High Photon Efficiency**
  - **Low Complexity**

Optical Communications Working Group

- **Published Books:**
  - Blue Book: Optical Communications Physical Layer
    - Covers the High Photon Efficiency Recommendations
  - Blue Book: Optical Communications Coding and Synchronization
    - Covers High Photon Efficiency
  - Green Book: Atmospheric Characterization For Optical Communication Systems
  - Magenta Book: Atmospheric Characterization and Forecasting for Optical Link Operations
  - ESA/DLR Orange Book: Optical High Data Rate Communications – 1064 nm

- **Books Completed but Awaiting Official Publication:**
  - NASA/CNES/JAXA/NICT Orange Book: Optical High Data Rate Communications – 1550 nm

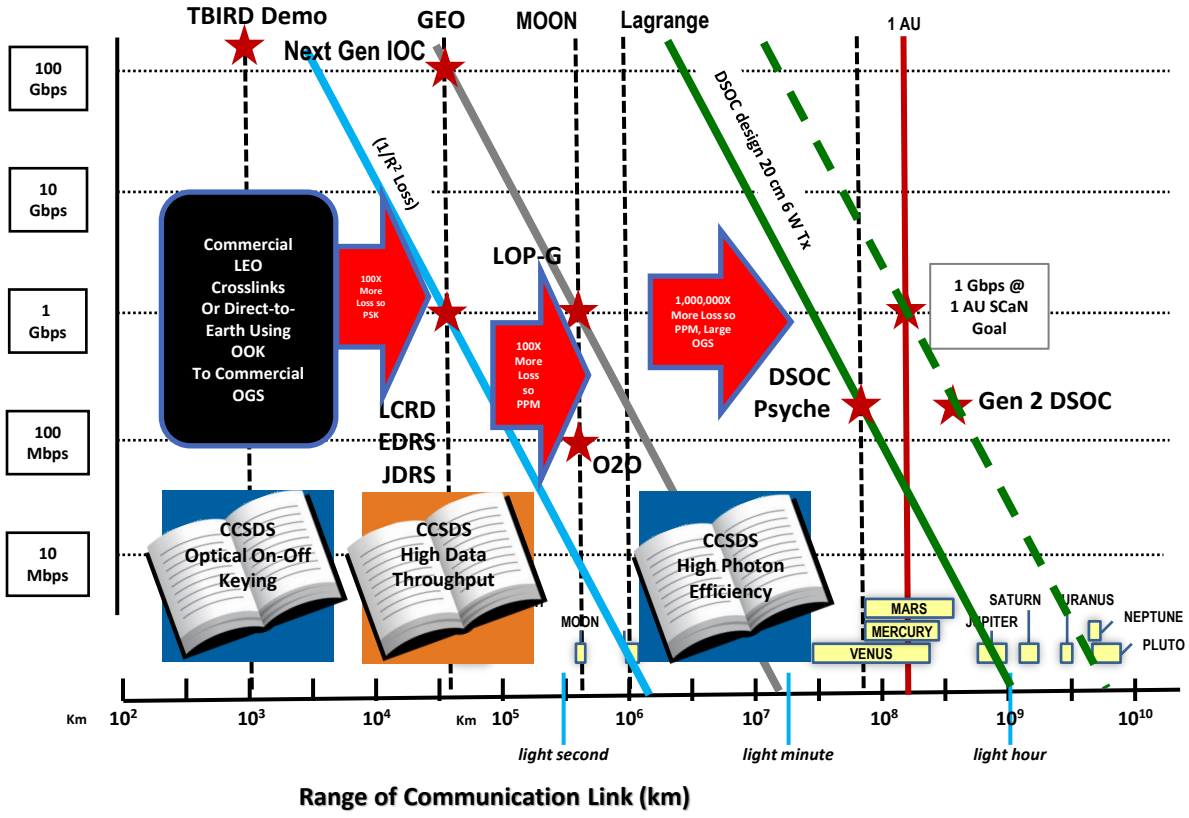
- **Books Completed but Awaiting Two Independent Prototypes:**
  - Revision 1 of the Blue Book on Optical Communications Physical Layer
    - Will include Optical On / Off Keying Recommendations

Optical Communications Working Group

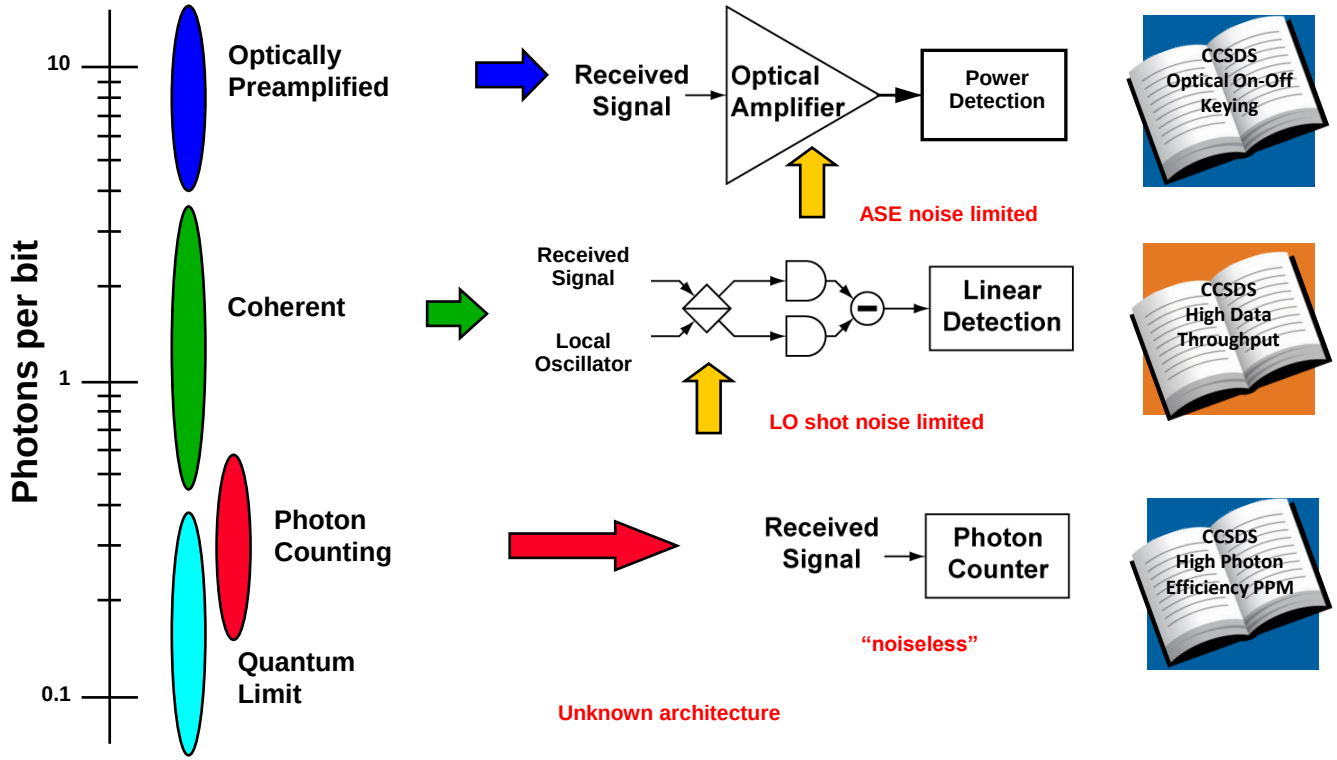
- **Books in Development:**
  - Revision 1 of the Blue Book on Optical Communications Coding and Synchronization
    - Will include Optical On / Off Keying Recommendations
    - The working group has basically reached consensus on the approach and just need to finalize the wording
    - However, two independent prototypes will be required before the book can be published

- **Future Work:**
  - Inclusion of Generic Framing Procedure in the appropriate CCSDS Books
    - Currently, it is only in the NASA/CNES/JAXA/NICT Orange Book: Optical High Data Rate Communications – 1550 nm
  - Adding Ranging and Time Transfer to High Photon Efficiency
  - Develop a Green Book on Optical Communications
    - Will provide background information and insights into how to use the Blue Books

CCSDS International Optical Communication Standards in Development

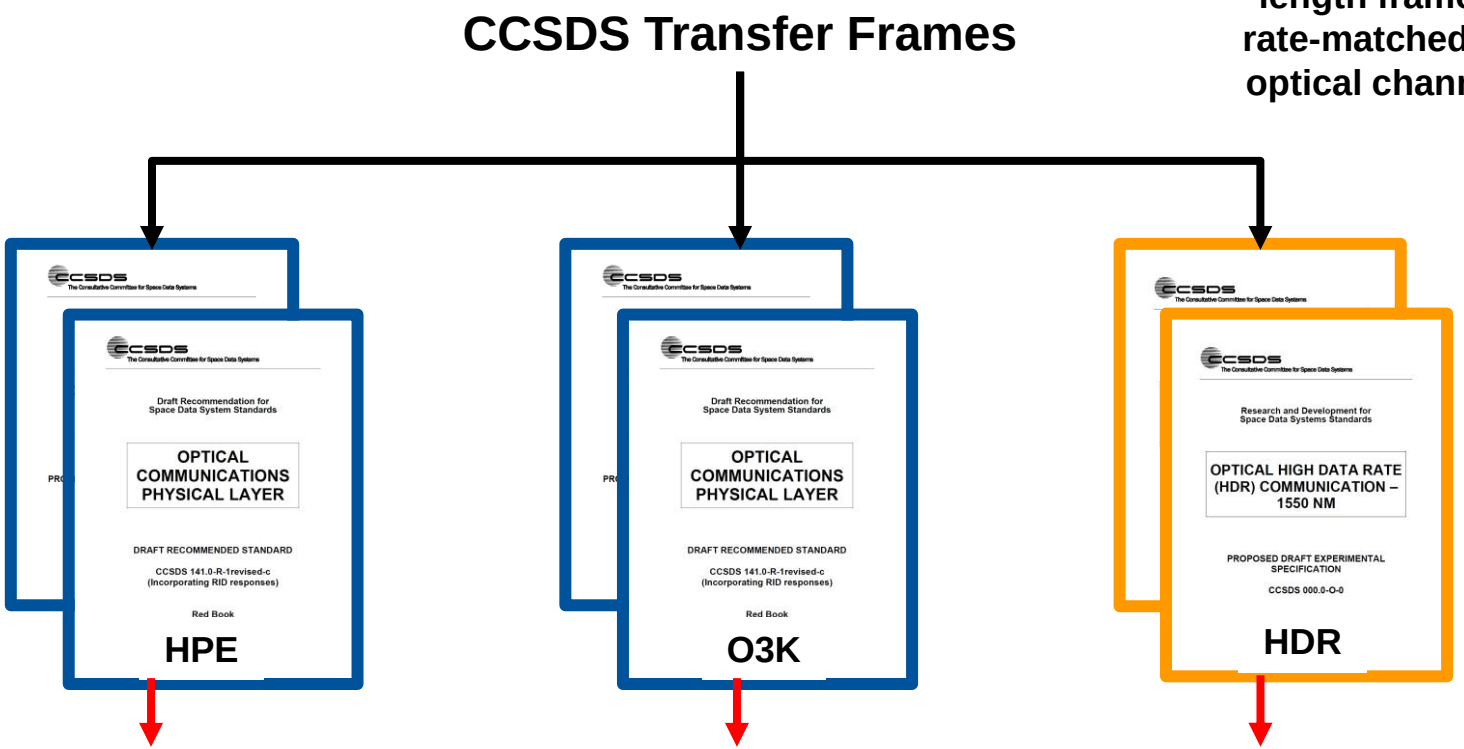


Detection Sensitivity in Optical Communications



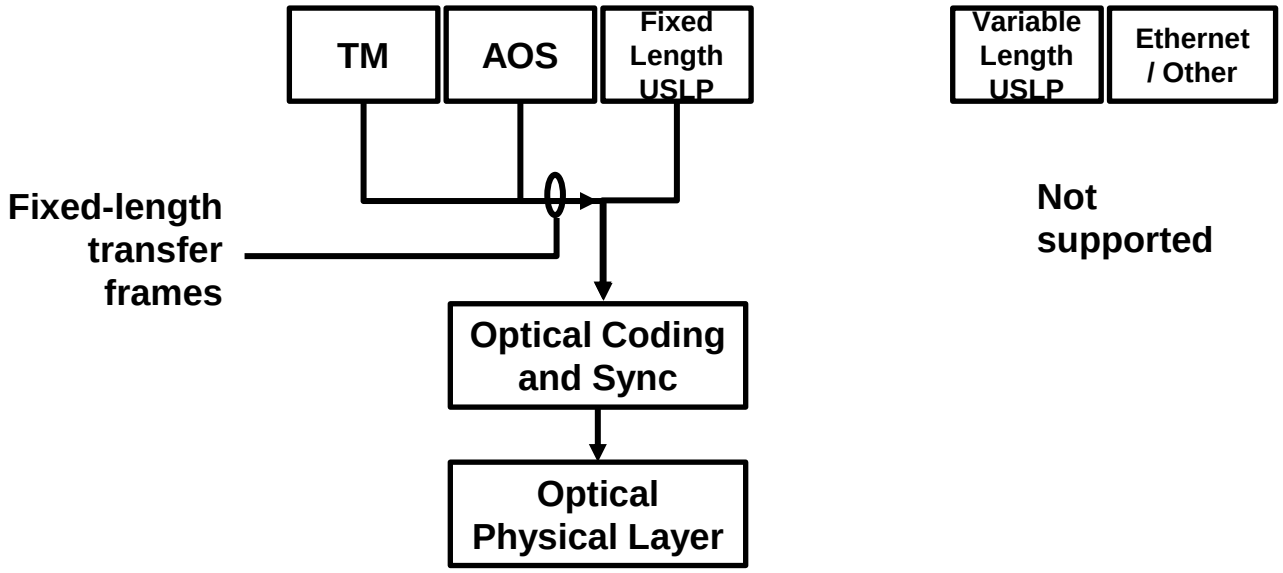
CCSDS Optical Signaling Today

Optical coding and sync layers accept fixed-length frames rate-matched to optical channel



Free-Space Optical Channel

Frame Transfer Services Provided by Current Optical Communications Recommendations

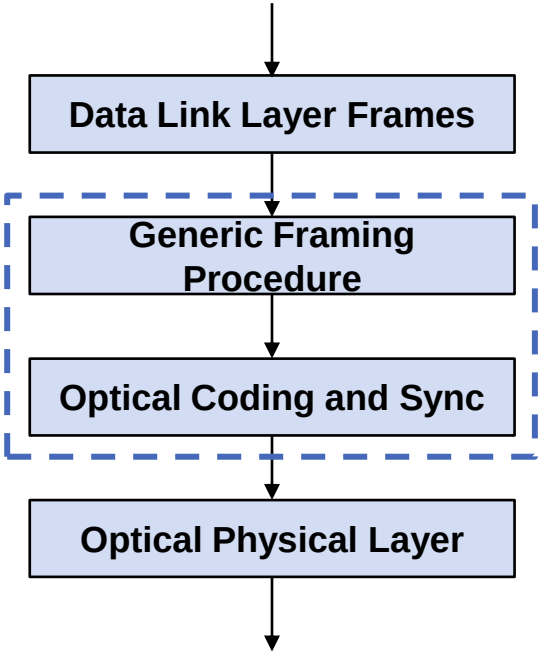


Optical communications signaling recommendations would be more widely applicable if they accepted variable-rate variable-length frames at the input to the coding and sync layer

Add Generic Framing Procedure (GFP)

- Augment existing CCSDS optical coding and sync layers to provide fixed-rate octet transport service in addition to fixed-rate fixed-length frame transport service
- Use Generic Framing Procedure (GFP, ITU-T G.7041/Y.1303) to adapt higher-layer frame formats to fixed-rate octet transport service
- Rationale:
  - Provides necessary means for transporting variable-length variable rate frames
  - Widely adopted industry standard for terrestrial optical transport systems (SDH, OTN)
  - Supports many common client interfaces and flexible enough to support other custom frame formats (e.g. CCSDS transport frames)

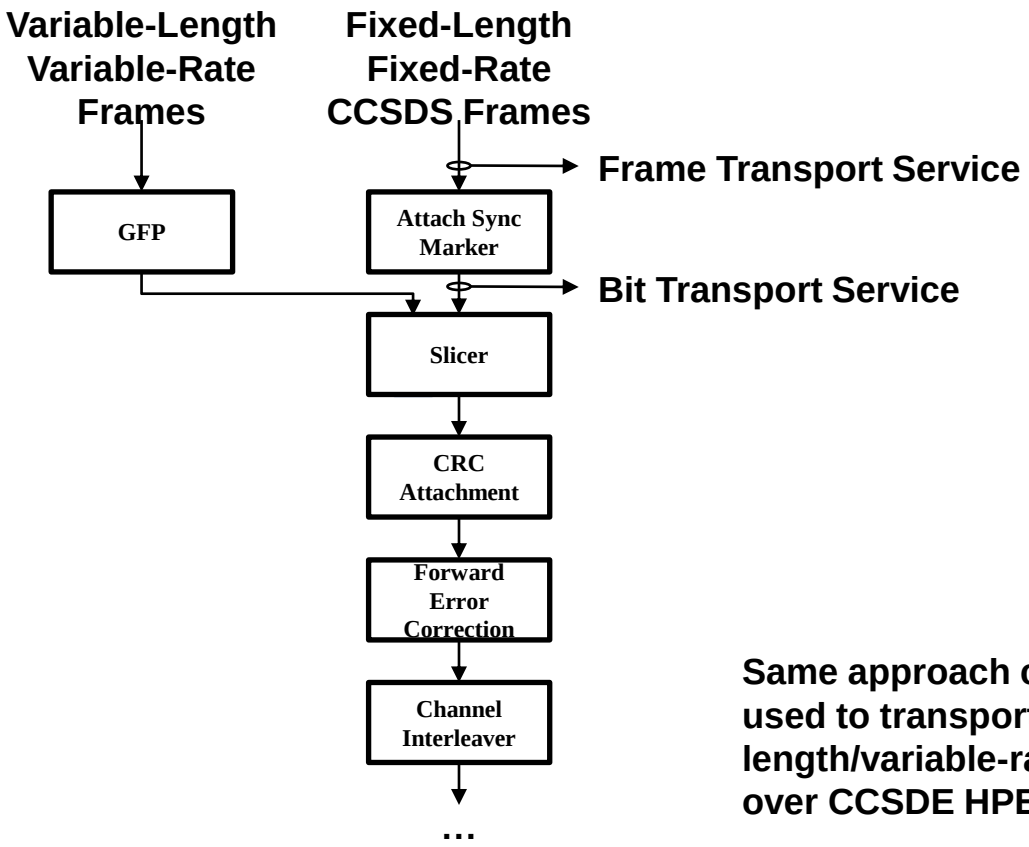
Generic Frame Transport via Generic Framing Procedure



Fixed/Variable Rate, Fixed/Variable Length Frames

Fixed Rate Octet Stream

Example: Using GRP with 1550 nm HDR Orange Book Recommendations



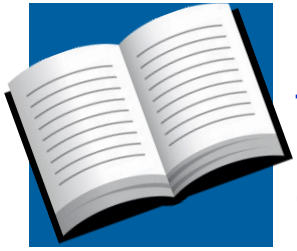
Same approach could be used to transport variable-length/variable-rate frames over CCSDE HPE or O3K

Conclusion

- **A set of standards for space optical communications is being developed by CCSDS to enable interoperability. An international standard will allow optical communications terminals built by one agency to use the infrastructure of another.**
  - **International cross support of optical communications is the evolutionary next step to follow today's RF cross support**
- **However, current CCSDS recommendations for optical signaling do not support transport of variable-length variable-rate frames.**
  - **The CCSDS working group is investigating the incorporation of Generic Framing Procedure (ITU G.7041) for handling variable-length, variable-rate frame inputs (e.g. USLP, Ethernet) to the optical coding and sync layers**

BACKUP

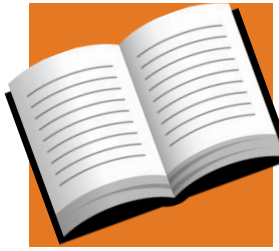
Field Guide to CCSDS Book Colors



BLUE BOOKS

Recommended Standards

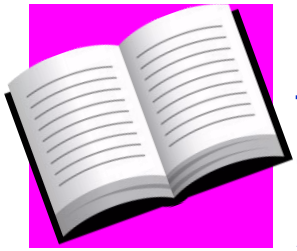
Normative and sufficiently detailed (and pre-tested) so they can be used to directly and independently implement interoperable systems (given that options are specified).



ORANGE BOOKS

Experimental

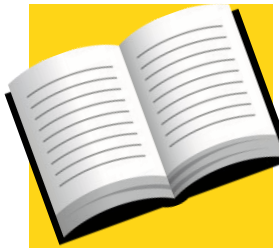
Normative, but may be very new technology that does not yet have consensus of enough agencies to standardize.



MAGENTA BOOKS

Recommended Practices

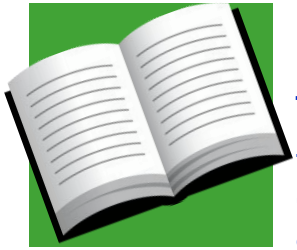
Normative, but at a level that is not directly implementable for interoperability. These are Reference Architectures, APIs, operational practices, etc.



YELLOW BOOKS

Administrative

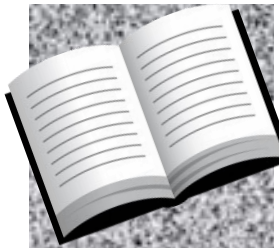
CCSDS Procedures, Proceedings, Test reports, etc.



GREEN BOOKS

Informative Documents

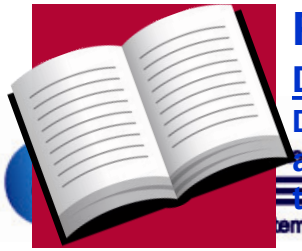
Not normative. These may be foundational for Blue/Magenta books, describing their applicability, overall archtecture, ops concept, etc.



SILVER BOOKS

Historical

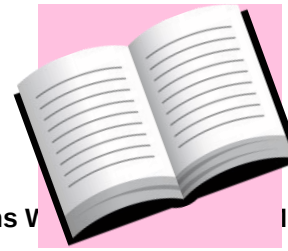
Deprecated and retired documents that are kept available to support existing or legacy implementations. Implication is that other agencies may not cross-support.



RED BOOKS

Draft Standards/Practices

Drafts of future Blue/Magenta books that are in agency review. Use caution with these… they can change before release.



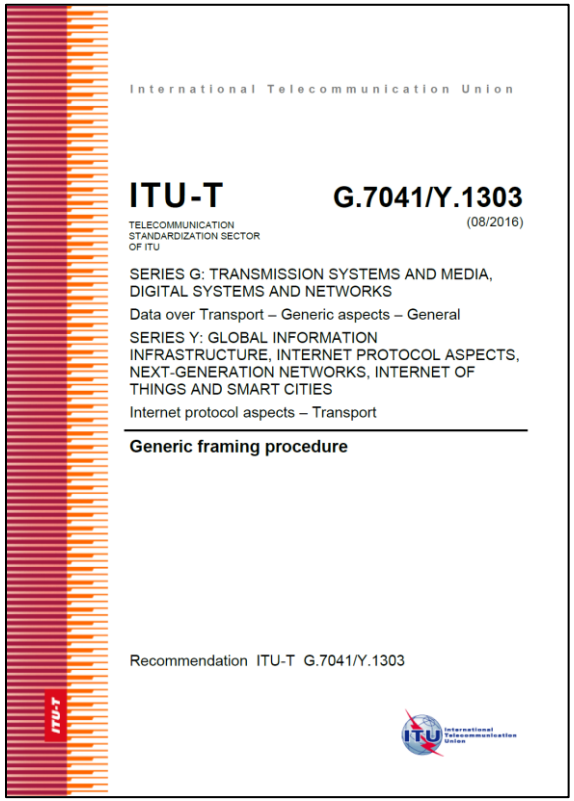
PINK BOOKS/SHEETS

Draft Revisions For Review

Draft Revisions to Blue or Magenta books that are circulated for agency review.

Pink Books are reissues of the full book,

GFP Description



International Telecommunication Union

ITU-T **G.7041/Y.1303**

TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

(08/2016)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Data over Transport – Generic aspects – General

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Internet protocol aspects – Transport

Generic framing procedure

Recommendation ITU-T G.7041/Y.1303